INLAND NAVIGATION AND CANALIZATION

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1 INTRODUCTION

This monograph describes the design of shallow-draft inland waterways in the United States (U. S.) by the U.S. Army, Corps of Engineers (USACE). The Corps maintains an 11,000-mile inland waterways system, Figure 1.1, with 211 locks at 168 sites and more than 180 navigation dams with normal heads from one ft to over 100 ft. This system handled more than 530 million tons of commerce in 1992, and total ton-miles that year was a record 271 billion (Antle and Grier, 1995).

Commodities moving on the system vary geographically and include coal, grain, petroleum, chemicals, and aggregates, all relatively low-value bulk materials. In the order of 50 percent of U.S. grain exports and 20 percent of coal exports move on the system. About 60 percent of electricity generated in the U.S. is coal-fired, and about 25 percent of this coal is transported by water (Antle and Grier, 1995).

Most inland navigation facilities in the U.S. are about 50 years old, and systems on some rivers, modernized in the past, are in need of rehabilitation or replacement at this time. Navigation locks and dams on the Upper Mississippi and Illinois Rivers were constructed in the 1930s, those on the Tennessee River in the 1950s and 60s, and those on the Ohio, Arkansas, and Columbia/Snake Rivers in the 1960s and 70s. The most recently completed systems are the Tennessee-Tombigbee Waterway opened in 1985 and the Red River Navigation Project, Louisiana, opened in December 1994. Modernization and replacement of older locks is continuing.

National objectives in developing rivers for safe and efficient inland navigation include:

a. Promoting the production and distribution of food resources.
b. Promoting the expansion of existing and development of new industrial production.
c. Enhancing economic development in general.
d. Enhancing social well-being.
e. Achieving these objectives while preserving and enhancing fish and wildlife resources and environmental quality.

Development of inland waterways for commercial navigation can be achieved in three general ways:

a. "Open river" development of rivers that have adequate flows to provide navigable depths in the navigation season.

b. "Canalized" development of rivers that do not have sufficient depths for navigation by a series of locks and dams to impound pools of adequate depth.

c. Canal development by excavating channels across land areas.

The type of development to be used on a specific river depends on local conditions and on costs if more than one type of development would be equally suitable. The primary consideration is whether or not flows will be adequate to provide sufficient depth in the "navigation season."

Local climate may limit the navigation season to periods of adequate rainfall or to warmer months in cold climates where ice blocks the river in winter. Also, high river stages and high velocities during floods interrupt navigation. The Upper Mississippi River freezes over every winter, and the river is closed to navigation from about early December to mid-March due to ice. The Upper Mississippi is also closed to navigation at other times of year during floods when the dams "go out of operation," (all spillway gates fully open) and pool levels are within 2 ft of the top of lock walls. At Lock and Dam 22, for example, this is a flow of 160,000. Navigation ceases on both the Arkansas River and the Red River at the 10 percent recurrence frequency when velocities and currents become too high for safe and efficient tow operation.

Few rivers, except in tidal reaches, have adequate dimensions and suitable velocities for open river navigation. Where streamflow does not naturally provide adequate depths for open-river development throughout the year, upstream reservoir storage may be used to provide controlled releases and adequate depths in downstream reaches. Depths can be increased also by stabilization and rectification work and by maintenance dredging, and levees may be used to confine flows to a designated floodway.

Canalization (systems of locks) is used to provide adequate depth for navigation in streams having little discharge and, therefore, depths too shallow for navigation; in a waterway having a steep slope and velocities too high for navigation; at a waterfall or rapids in a stream that otherwise provides adequate depth in other reaches.

Canals cut through land generally are used to connect two bodies of water and to bypass rock outcrops and rapids in rivers. Canals are expensive, requiring acquisition of large tracts of land for the canal and for disposal of excavated material, and canal banks often require protection from wave damage because of the restricted channel width.

Development of safe and efficient inland navigation is based on providing the following:

a. Channels of adequate dimensions (depth and width) for navigation.

b. Safe streamflow velocities that are not a hazard to navigation traffic.

c. Harbors and related appurtenances for receipt and shipment of commodities.

d. Compatibility of navigation requirments with other developments, including flood protection works, transportation networks (roads, railroads), and utility crossings.

Navigation projects typically include such basic components as:

a. Spillway (gated, uncontrolled, or wickets).
b. Overflow weir or embankment.
c. Non-overflow embankment.
d. Locks.
e. Navigable pass.
f. Outlet works.
g. Water quality enhancement facilities.
h. Fish passage facilities.
i. Aids to navigation.

Additionally, facilities for generation of hydroelectric power, releases for irrigation or stream maintenance, and recreation may be included, depending on local conditions.

Planning, design criteria, and operating procedures for navigation projects should consider measures to avoid or minimize adverse ecological impacts, mitigate adverse effects, and provide environmental enhancement. Particular concerns in the United States (U.S.) are to improve low dissolved oxygen levels downstream of dams by flow aeration and to prevent nitrogen supersaturation on high spillways.

Figure 1.1. Shallow-draft Inland Waterways System, United States.